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Characterizing Musculoskeletal Injury among Aeromedical Evacuation Personnel: An Observational Study

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14. ABSTRACT

This study aimed to identify factors that increase the risk of musculoskeletal injuries (MSIs) to aeromedical evacuation (AE) personnel. The costs associated with MSIs (medical expenses and lost duty time) burden military populations. Occupational hazards, including heavy lifting and awkward posture, contribute to MSI development. Physically demanding AE tasks likely place AE crewmembers (AECMs) at an increased risk for MSIs. This study included three phases: a sampling study, laboratory observations, and field observations. In Phase I, 43 active duty AECMs volunteered to complete a questionnaire identifying AE tasks they associate with MSIs. In Phase II, researchers applied a Quick Exposure Check technique to characterize the ergonomic risk of 15AECMs while completing the five highest risk tasks identified in Phase I. Phase III included field observations on flight lines at Ramstein Air Base and Joint Base Andrews. The sampling study found that aircraft configuration and patient loading are the two tasks most often associated with MSIs. Aircraft configuration was associated with neck, wrist, and leg injuries, while patient loading was associated more often with shoulder and back pain. Survey respondents also noted the airstairs of the KC-135 and litter support straps on the C-130 as ergonomic challenges. The tasks identified in Phase I and further evaluated in Phase II were aircraft configuration, loading loose equipment, loading litter equipment, loading litter patients, and unloading litter patients. Phase II efforts characterized loading litter equipment, loading litter patients, and unloading litter patients as the highest risk for back, shoulder, and arm pain. Phase III field observations confirmed the Phase II findings, with loading and offloading of litters achieving a moderate risk score. This multi-phased study identified ergonomic challenges in AE tasks and provided process and materiel recommendations to mitigate these risks for this population.

15. SUBJECT TERMS

Musculoskeletal injuries, aeromedical evacuation, ergonomic interventions, occupational health hazards

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1.0 SUMMARY

This study aimed to identify risk factors associated with the development of musculoskeletal injuries (MSIs) in aeromedical evacuation crewmembers (AECMs). MSIs are a primary health concern among the military population and cost the military in healthcare expenditures as well as lost duty time. Occupational hazards such as heavy lifting and awkward postures may put AECMs at increased risk for developing MSIs. This study comprised three phases: a sampling study, laboratory observations, and field observations.

In Phase I, a sampling study identified which AE tasks AECMs associated with MSIs. In Phase II, an ergonomic assessment in a laboratory quantified the risk associated with the top five tasks identified from the sampling study using the Quick Exposure Check methodology. In Phase III, the study team conducted field observations using an adapted SMTRA scoring technique during aircraft configuration and patient loading at Ramstein Air Base and patient unloading at Joint Base Andrews to supplement the laboratory conclusions from Phase II.

In the sampling study (Phase I), AECMs associated the following five tasks with an increased risk of MSIs: aircraft configuration, loading loose equipment, loading litter equipment, loading litter patients, and unloading litter patients. Aircraft configuration was commonly associated with neck, wrist, and leg pain, while patient loading was more often associated with shoulder and back pain. Additionally, the qualitative data from the sampling study identified the loading of gear and patients up the airstairs of the KC-135 and hanging straps on the C-130 as unique platform challenges. Quantitative assessments from Phase II identified loading litter equipment, loading litter patients, and unloading litter patients as tasks posing the greatest risk for MSIs in the back, shoulder, and arm regions. Phase III field observations supplemented the Phase II findings by identifying the loading and offloading of litters as posing a moderate risk level.

This multi-phased study identified and quantified the risk associated with occupational tasks, which may place AECMs at an increased risk for MSIs. Study findings informed materiel and process recommendations aimed to mitigate MSI risks in the AE environment.

2.0 INTRODUCTION

Musculoskeletal injuries (MSIs) result from the cumulative trauma associated with repetitive and physically demanding tasks. Mentally and physically strenuous environments have been shown to increase the likelihood of MSIs [1]. Within the military, MSIs are a leading cause of unit attrition. Disease and non-battle injuries, which include MSIs, account for more casualties than combat-related injuries [2-5]. MSIs increase morbidity and are the most common reason military personnel seek medical care [2,4,6]. MSIs compromise the health and effectiveness of military personnel and cost the military greatly in lost duty time and healthcare expenses [1,3,5,7]. Thus, it is important to mitigate ergonomic risks whenever possible in military environments.

Aeromedical evacuation crewmembers (AECMs) support the critical mission of transporting ill and injured service members. It is likely ergonomic risks exist within the AE environment, potentially putting AECMs at increased medical risk over their ground-based counterparts. An AE crew for a standard mission typically consists of two nurses and three medical technicians. AECMs are medical personnel with specialized training for the flight environment and are aircrew members. As with most military populations, the mitigation of MSI risks to optimize health and performance of the member is critical to ensuring mission success.

Multiple studies have highlighted an increased risk of MSIs within civilian healthcare sectors due to the physically stressing demands of the job [8-10]. These same risks exist in military healthcare facilities, and the flight environment may exacerbate the risks in AECMs. In addition to providing care to multiple patients of varying states of acuity, AECMs face additional challenges presented from the stresses of flight (fatigue, thermal changes, vibration, decreased partial pressure of oxygen, barometric pressure changes, gravitational forces, noise, and dehydration) [11]. Before flight, AECMs manually configure and load the equipment on the aircraft. AECMs also support the patient loading process. During flight, AECMs are responsible for providing care to multiple patients located at various litter and seat positions for extended durations, sometimes greater than 8 hours. Once the flight is complete, AECMs support the unloading process. To accomplish these common AE tasks, AECMs are often in awkward postures and lifting heavy loads. These factors in combination with the stresses of flight may exacerbate the risk for MSIs in this environment.

While several studies have investigated MSI risks in the civilian healthcare sector [8-10], there is limited research on the risk of MSIs within military populations, especially for aeromedical evacuation. This study aimed to identify and quantify the risks of MSIs associated with AE transport tasks, guide materiel solutions, and recommend process changes to mitigate the risks of MSIs within the AE environment.

3.0 METHODOLOGY

3.1 Institutional Review

This study received expedited approval by the Air Force Research Laboratory Institutional Review Board (approval number FWR20130081H).

This study utilized a multi-phased research design including a sampling study of AECMs, laboratory observations at the United States Air Force School of Aerospace Medicine (USAFSAM) AE training facilities located at Wright-Patterson Air Force Base, and field observations at Ramstein Air Base and Joint Base Andrews.

3.2 Phase I: Survey

Phase I provided a foundation for the subsequent phases by seeking input from AECMs on the perceived prevalence of MSIs in their career field and gathered information on tasks that AECMs associate with musculoskeletal pain. The questionnaire, provided in Figure 1, was modeled after a survey used by Esser et al. [12] and was administered via SurveyMonkey to volunteers from the USAFSAM Education and Training Department and the four active duty AE squadrons. The questionnaire included three sections: demographics and AE role (independent variables), symptoms by body region, and work experience and activity (dependent variables). The data collected included gender, AE role, height, weight, pain frequency, work restrictions, work absences, and injury occurrence by body region (neck, shoulder, wrist, back, and leg). The data were gathered and organized in Excel (Microsoft, Redmond, WA). A frequency count comparison of each category by body region symptom and the AE tasks associated with the injury region was conducted. Qualitative analysis utilized a word count assessment for each of the open field responses to each injury category.

MUSCULOSKELETAL INJURY IN AE QUESTIONNAIRE

1. DEMOGRAPHICS

1a. Please indicate your gender: M F

1b. Please indicate your AE role: Nurse Medical Technician

1c. What is your height (in inches)?

1d. What is your weight (in lbs)?

2. SYMPTOMS BY BODY REGION

Please indicate how often you had pain resulting from AE duties in the following body regions:

NECK	Never	Very Rarely	Rarely	Occasionally	Frequently	Very Frequently
SHOULDER	Never	Very Rarely	Rarely	Occasionally	Frequently	Very Frequently
WRIST	Never	Very Rarely	Rarely	Occasionally	Frequently	Very Frequently
BACK	Never	Very Rarely	Rarely	Occasionally	Frequently	Very Frequently
LEG	Never	Very Rarely	Rarely	Occasionally	Frequently	Very Frequently

3. WORK EXPERIENCE AND ACTIVITIES

3a. How many years have you served on AE assignments?

0-2 3-5 6-8 9-11 >12

3b. Please indicate the AE task, if any, that is most likely to result in the highest likelihood of injury in the following body regions? (Please indicate a specify task and aircraft, if appropriate, in the other field.)

NECK INJURY	Aircraft Configuration	Patient Loading	Patient Care during Flight	Patient Off Loading	Specific Task:_________	Aircraft: _______
SHOULDER INJURY	Aircraft Configuration	Patient Loading	Patient Care during Flight	Patient Off Loading	Specific Task:_________	Aircraft: _______
WRIST INJURY	Aircraft Configuration	Patient Loading	Patient Care during Flight	Patient Off Loading	Specific Task:_________	Aircraft: _______
BACK INJURY	Aircraft Configuration	Patient Loading	Patient Care during Flight	Patient Off Loading	Specific Task:_________	Aircraft:
LEG INJURY	Aircraft Configuration	Patient Loading	Patient Care during Flight	Patient Off Loading	Specific Task:_________	Aircraft: _______

3c. During your career, how many work restrictions have you received due to musculoskeletal injuries or pain resulting from AE duties?

None 1 2 3 4 or more

3d. During your career, how many workday absences have resulted from musculoskeletal injuries or pain resulting from AE duties ?

None 1 2 3 4 or more

Figure 1. Phase I questionnaire.

IBM Statistical Package for the Social Sciences (SPSS) Statistics for Windows, Version 20.0 (IBM, Armonk, NY) was used for the statistical analysis. Chi-squared analyses were used to determine if differences existed in the reporting of musculoskeletal pain based on demographic variables. Fisher's exact test statistics were calculated to determine if differences existed in the reporting of MSI-related lost duty days or restricted duty status based on demographic variables. Pearson correlation values were calculated to find the strength of the correlation between variables. For all analyses, a p-value of less than 0.05 was considered statistically significant.

3.3 Phase II: Laboratory Observations

During Phase II, the study team completed laboratory observations of AECMs from USAFSAM and the Formal Training Unit both located at Wright-Patterson Air Force Base completing five AE tasks in a simulated C-130 training facility located at USAFSAM. Responses from the sampling study in Phase I informed the five tasks selected for assessment in Phase II. These tasks included aircraft configuration, loading loose equipment, loading litter equipment, loading litter patients, and off-loading litter patients. Three crews of five participants each completed the series of tasks with three repetitions. Each study investigator assessed one participant from each AE crew.

Study investigators used the Quick Exposure Check (QEC) [13] to quantify the risk of MSIs involved in completing each task. The QEC is a tool used to assess exposure to musculoskeletal risk factors for multiple body sites [13-15]. This tool combines feedback from the observer and the participant to rate the exposure risk of work-related MSIs. It focuses on the back, shoulder/arm, wrist/hand, and neck. This tool has received positive assessments regarding usability, sensitivity, inter-/intra-observer reliability, and measurement validity [15] and, as such, was selected for use by the study team.

Each member of the study team completed training on proper use of the tool. During the assessment, observers filled out an Observer Worksheet on their respective participant as shown in Figure 2, and participants completed a Worker's Worksheet on their task as shown in Figure 3. The scoring for each task and anatomical region was determined by combining the scores from the observer and the participant using the task assessment scorecard as shown in Figure 4. The final scores yielded the associated exposure level for each anatomical region. This assessment did not include the back (static) category, since all tasks evaluated the participants while moving. The QEC exposure level scoring matrix used for this study is provided in Table 1.

The study team videotaped all assessments to aid in the analysis process. Once the laboratory observations were complete, the study team reviewed the recordings to confirm the scoring assigned to each task. Findings from Phase II informed the tasks observed during the field observations in Phase III.

OBSERVER WORKSHEET

Subject Number: ________________ Task: ______________________

BACK

A. When performing the task, is the back?
A1 Almost neutral
A2 Moderately flexed or twisted or side bent
A3 Excessively flexed or twisted or side bent

B. For lifting, pushing/pulling and carrying tasks. Is the movement of the back?
B3 Infrequent (around 3 times per minute or less)
B4 Frequent (around 8 times per minute)
B5 Very Frequent (around 12 times per minute or more)

SHOULDER/ARM

C. When the task is performed, are the hands
C1 At or below waist level
C2 At about chest height
C3 At or above shoulder height

D. Is the shoulder/arm movement
D1 Infrequent (some intermittent movement)
D2 Frequent (regular movement with some pauses)
D3 Very frequent (almost continuous movement)

WRIST / HAND

E. Is the task performed with the wrist
E1 An almost straight wrist
E2 A deviated or bent wrist

F. Are similar motion patterns repeated
F1 10 times per minute or less
F2 11 to 20 times per minute
F3 More than 20 times per minute

NECK

G. When performing the task, is the head/ neck bent or twisted?
G1 No
G2 Yes, occasionally
G3 Yes, continuously

Figure 2. QEC observer worksheet (adapted from [13]).

WORKER'S WORKSHEET

Subject Number: ____________________ Task: ____________________________

H. Is the maximum weight handled manually by you in this task?
H1 Light (5 kg or less)
H2 Moderate (6 to 10 kg)
H3 Heavy (11 to 20 kg)
H4 Very heavy (more than 20 kg)

J. On average, how much time do you spend per mission on the task?
J1 Less than 2 hours
J2 2 to 4 hours
J3 More than 4 hours

K. When performing this task is the maximum force level exerted by one hand?
K1 Low (e.g. less than 1 kg)
K2 Medium (e.g. 1 to 4 kg)
K3 High (e.g. 1 to 4 kg)

L. Is the visual demand of this task
L1 Low (almost no need to view fine details)
L2 High (need to view some fine details)
If High, please provide additional information below:

M. Do you experience any vibrations during this task?
M1 Less than 1 hour per mission or never
M2 Between 1 and 4 hours per mission
M3 More than 4 hours per mission

N. Do you have difficulty keeping up with this work?
N1 Never
N2 Sometimes
N3 Often
If often, please provide additional details below:

O. In general, how stressful do you find this job?
O1 Not at all stressful
O2 Mildly stressful
O3 Moderately stressful
O4 Very stressful
If moderately or very, please give details below:

Figure 3. QEC worker's worksheet (adapted from [13]).

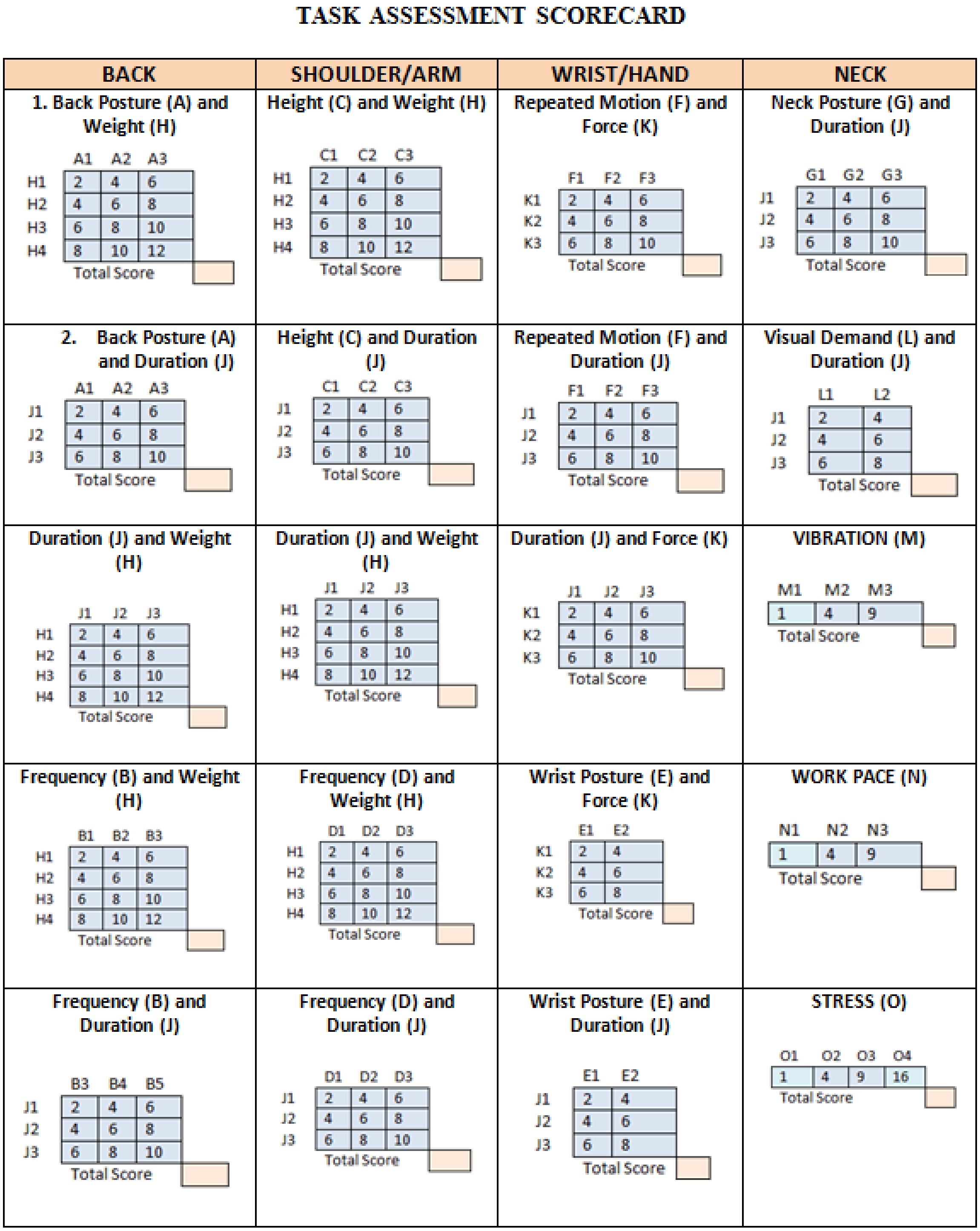

Figure 4. Task assessment scorecard (adapted from [13]).

Table 1. QEC Exposure Level Scoring Matrix (adapted from [13])

Anatomical Region	Exposure Level			
	Low	Moderate	High	Very High
Back (Moving)	10-20	21-30	31-40	41-56
Shoulder/Arm	10-20	21-30	31-40	41-56
Wrist/Hand	10-20	21-30	31-40	41-56
Neck	4-6	8-10	12-14	16-18

3.4 Phase III: Field Observations

In Phase III, two study team members conducted field observations of AE personnel at Ramstein Air Base in Germany and Joint Base Andrews in Maryland. These observations were intended to contribute additional insight on the risks associated with AE tasks. Specifically, investigators monitored crews as they configured the aircraft, loaded equipment, and loaded patients on a C-17 airframe; these were the tasks identified from Phase II as having the highest risk for MSIs. Additionally, the unloading of patients was also observed. Researchers utilized an adapted SMTRA technique in the field observations to score the risk of MSIs associated with these tasks. The SMTRA assessment tool was provided by Dr. Robin Burgess-Limerick, co-developer of the Manual Risk Assessment (ManTRA) tool [16], and can be used to assess musculoskeletal risk factors associated with manual tasks in the workplace (Burgess-Limerick R. Personal communication; 2013). The tool was selected due to its applicability for field observations, as it does not require feedback from the participant observed. Each observer rated various aspects of the tasks completed by the AE personnel (exertion, exposure, posture, and movement) for four primary body regions (arms, shoulder, legs, and back).

4.0 RESULTS

4.1 Phase I: Survey

In total, 45 AE personnel completed the questionnaire in Phase I including four incomplete questionnaires. Of the respondents, the male/female ratio was 20/21 and the nurse/medical technician role ratio was 27/14. For body mass index (BMI) calculations, the standard classifications were used as follows: <18.5 underweight, 18.5-24.9 normal, 25-29.9 overweight, >30 obese [17]. Males had a statistically higher BMI than females ($p = 0.004$). There was no significant difference for BMI between the medical technicians and nurses.

The questionnaire included questions on frequency of MSI symptoms in various body regions and the AE tasks AECMs associated with these symptoms. Back pain was the most frequently reported symptom associated with AE duties, with 16 individuals (39%) stating they *occasionally* had back pain, 4 individuals (10%) stating they *frequently* experienced back pain, and 5 individuals (12%) stating they *very frequently* experienced back pain. As shown in Table 2, patient loading and aircraft configuration were the two tasks AECMS most often associated with MSI symptoms.

Table 2. Frequency of MSI Symptoms

Frequency	Back	Shoulder/ Arm	Wrist/Hand	Neck	Leg
Never	7	12	20	15	19
Very Rarely	4	3	8	8	3
Rarely	5	10	6	6	12
Occasionally	16	11	5	7	1
Frequently	4	5	1	5	6
Very Frequently	5	0	1	0	0
Most Common Task Associated with Pain	patient loading	patient loading	aircraft configuration	aircraft configuration	aircraft configuration

There were no significant differences found based on gender or AE role in the frequency of pain responses for any of the body regions. Males reported missing significantly more duty days due to MSIs self-associated with AE tasks compared to females ($p = 0.048$). In many cases, as shown in Table 3, reported pain in one region of the body significantly correlated with reported pain in other body regions. Self-reported missed duty days significantly correlated with self-reported restricted duty status.

Table 3. Pearson Correlation Values of MSI Symptoms

	Neck Pain	Shoulder Pain	Wrist Pain	Back Pain	Leg Pain	Restricted Duty Days	Missed Duty Days
Neck Pain							
Shoulder Pain	0.761[a]						
Wrist Pain	0.266	0.283[a]					
Back Pain	0.536[a]	0.505[a]	0.269				
Leg Pain	0.587[a]	0.565[a]	0.336[a]	0.562[a]			
Restricted Duty Days	0.158	0.189	0.077	0.548[a]	0.331[a]		
Missed Duty Days	0.218	0.100	0.132	0.345[a]	0.252	0.406[a]	

[a]Signifies significance.

Aircraft configuration was identified as the most common task associated with neck (51%), wrist (41%), and leg (46%) pain, while patient loading was identified as the most common task associated with shoulder (59%) and back (51%) pain. Qualitative responses indicated that hanging the straps used for aircraft configuration on the C-130 and the loading of gear and patients up the airstairs on the KC-135 posed unique platform-specific challenges to aircrew.

4.2 Phase II: Laboratory Observations

Phase II identified loading litter equipment, loading litter patients, and unloading litter as high-risk tasks for MSIs in the back, shoulders, and arms. The QEC scores are in Table 4.

Table 4. QEC Risk Scores for AE Tasks

AE Task	Back (Moving)	Shoulder /Arm	Wrist/ Hand	Neck
Aircraft Configuration	21 (M)	27 (M)	18 (L)	8 (M)
Loading of Loose Equipment	30 (M)	26 (M)	22 (M)	6 (L)
Loading of Litter with Equipment	31 (H)	32 (H)	21 (M)	8 (M)
Loading Litter Patients	33 (H)	34 (H)	24 (M)	8 (M)
Unloading Litter Patients	33 (H)	34 (H)	22 (M)	8 (M)

Note: L designates low exposure level, M designates moderate exposure level, and H designates high exposure level.

In addition to the QEC tool, the tasks were videotaped to confirm scores post-observation, and qualitative notes from the researchers and participants were reviewed. Key observations from the qualitative notes indicated moving the portable therapeutic liquid oxygen (PTLOX) system and utilizing the hanging straps during configuration posed risks for several participants. Specifically, it was noted that challenges often arose from twisted litter support straps and difficulty accessing the straps, which are located at the top of the airframe and are reached by climbing to the top of a litter stanchion.

4.3 Phase III: Field Observations

Phase III findings further supported the findings from Phase II, with patient loading and configuration of the aircraft posing moderate risks according to the adapted SMTRA technique. The highest risk for back pain occurred during the loading and unloading of patients on the lowest tier of the litter stanchion on the C-17 airframe, as shown in Figure 5. The unloading of patients from the lowest tier of the litter stanchion resulted in the greatest risk to AECMs' lower extremities. The risk scores from the observations during Phase III are included in Table 5.

Figure 5. Litter stanchion on a C-17 airframe.

Table 5. Phase III Risk Scores for AE Tasks

AE Task	Back	Arms	Shoulders	Legs
Upper Tier Loading	8	9	7	5
Mid-Tier Loading	8	4	10	4
Lower Tier Loading	10	8	5	5
Running Lines	5	8	8	4
Stanchion Configuration	9	5	5	5
Upper Tier Unloading	6	6	6	6
Mid-Tier Unloading	9	5	6	6
Lower Tier Unloading	10	7	7	7

5.0 DISCUSSION

Phase I data did not indicate a statistically significant difference in the frequency of pain experienced between males and females or medical technicians and nurses. Phase I questionnaire respondents reported back pain the most frequently followed by shoulder pain. The frequency of back pain reported agrees with anecdotal reports from the AE community and is a common theme among MSI studies on civilian healthcare providers involved in patient movement [8-10].

Self-reported work restrictions significantly correlated to self-reported missed workdays. This association seems reasonable, since oftentimes MSIs result from cumulative trauma [9,18] and overuse of a specific body region over time and may contribute to both restricted duty status and missed workdays [10]. These findings are of significant importance, as short-term work restrictions of less than 2 weeks could have effects on the healthcare provider's well-being and productivity, with additional implications on a provider's potential for re-injury and the safety of the patient [10]. In many cases, self-reported pain in one region significantly correlated to pain in other body regions. One example of this is shoulder pain, which was correlated with pain in all of the other body regions examined (back, leg, wrist, and neck). This may be due to the manner in which an individual with an MSI may compensate for the pain in one region by using alternate lifting techniques or overusing another area, which may exacerbate pain in other regions.

Patient loading was frequently attributed to injury experienced in the back and shoulder regions. Patient loading is a physically demanding task that requires personnel to lift and maneuver heavy loads. Thus, it is not surprising this task is associated with shoulder and back pain, as heavy lifting has been associated with MSIs in several past studies [19-21]. Qualitative data on the questionnaire indicated the airstairs used to load and unload the KC-135 posed additional ergonomic challenges. Specifically, respondents described the airstairs as difficult to climb while carrying equipment and/or patients. Aircraft configuration was self-associated with neck, wrist, and leg pain by questionnaire respondents. Aircraft configuration is platform specific and involves various tasks such as setting up stanchions, running oxygen lines, and hanging straps, many of which require excessive reach and non-neutral postures, thus increasing the risk of developing musculoskeletal pain [22].

Phases II and III confirmed Phase I data by quantifying, through investigator observation and standardized metrics, the risks described in the questionnaire responses. The information obtained in Phases II and III supported the development of ergonomic recommendations to mitigate the risk of MSIs in AE personnel discussed in section 7.0 in this report. Additionally, these data serve as baseline measures that can be repeated to assess the reduction in risk following the integration of changes to mitigate MSIs in this population.

6.0 LIMITATIONS

Confounding variables such as physiological characteristics of the participants were not controlled for or collected during this study. Preexisting conditions and medical histories relating to MSIs were not identified. Therefore, it is unknown if participants had preexisting MSIs that could have introduced bias into their questionnaire responses. Preexisting MSIs may have caused participants to alter their lifting techniques during the laboratory and field assessments. Altered lifting techniques may have resulted in compensation in other body regions and may have influenced the risk scoring of the AE tasks.

BMI and associated variables were not collected or controlled during Phases II and III. Findings from Phase I indicate there was a statistically significant difference associated with BMI between the male and female subjects. There was not a statistically significant difference in BMI between the medical technicians and nurses in this phase. Additionally, there is a strong emphasis on maintaining physical fitness to ensure tactical readiness in the military. Therefore, the range of BMI measures may likely be smaller for a military population compared to a civilian population.

Different platforms were assessed during different phases of this study. Phase II focused on a C-130, whereas Phase III focused on a C-17. No observations were made on a KC-135; thus, all issues identified for this platform resulted from questionnaire responses.

7.0 RECOMMENDATIONS

Study data informed materiel and process recommendations to improve ergonomics to mitigate the MSI risk associated with the four highest ranking tasks: aircraft configuration (C-130 and C-17), patient loading, and equipment loading. The tasks and their corresponding solutions are included in Table 6.

Table 6. Suggested Ergonomic Improvements to Decrease MSI Risks

Task	Materiel Solution	Process Solution
C-130 Configuration	Consider a redesign of the stanchion support strap.	Consider AECM height in task delegation when possible.
C-17 Configuration	Consider development of a movable stanchion rack.	Consider AECM height in task delegation when possible.
Patient Loading	Consider adapting a gurney system for AE patient loading purposes.	Use lifting teams of similar height individuals when possible. When loading, have shortest people carrying the litter walk up the ramp first.
Equipment Loading	Develop a dolly system to support PTLOX loading.	Use box trucks instead of smaller vehicles when possible to haul equipment to flight line.

One materiel solution for the C-130 aircraft configuration task is the redesign of the strap system in the C-130. One concept is to develop a retractable strap fixed to the stanchion alongside existing stanchion rungs. This would allow AE personnel to load litters without setting up straps or hanging straps from the top of the fuselage. This would require less reaching and reduce the awkward posture of the AECM associated with current strap configurations. A second option is to develop retractable straps to prevent the challenges associated with untangling the straps prior to use. A process recommendation for the C-130 configuration involves tasking crewmembers by height whenever feasible so taller members are tending to tasks at increased elevations, such as adjusting higher straps, while shorter crewmembers are completing lower tasks, thus improving the postures for both populations.

The development of a moveable stanchion rack would aid in setting up stanchions in the C-17 and a jump seat stool that would assist AECMs in hanging lines. Figure 6 provides an example of the rack concept. This concept would prevent excessive lifting, as crewmembers could wheel stanchions and crossbars alongside them as they configured the aircraft.

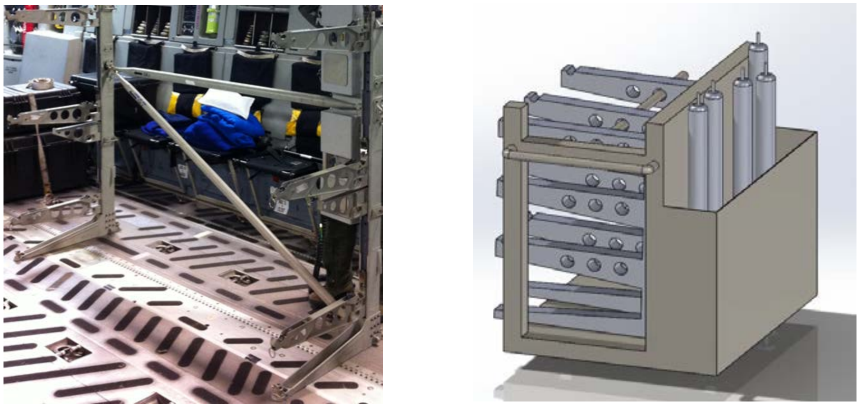

Figure 6. Stanchion rack concept for the C-17.

The jump seat stool concept, one example shown in Figure 7, could be used to reduce excessive reaching, as crewmembers could stand on top of it to more easily reach oxygen and electrical lines. A possible process change would be having taller personnel run lines to lessen excessive reaching while shorter personnel set up stanchions to reduce awkward postures.

Figure 7. Step stool concept for hanging lines during C-17 configuration.

Patient loading involves heavy lifting while sometimes in awkward postures. To lessen this, a motorized and hydraulic gurney could be used. While current regulations [23] forbid the use of ambulance-type stretchers for patient movement up or down aircraft ramps, this concept, if designed specifically for AE operations, would likely reduce the physical demands associated with patient loading and unloading and may be worth considering as a future ergonomic improvement for this community. A process recommendation is to organize personnel in lift crews based on height when feasible.

To mitigate risks associated with loading equipment, a dolly system could be added to the PTLOX system. A dolly system would allow the PTLOX to be rolled onto the aircraft. A process solution for equipment loading is to use box trucks to deliver and load equipment when available. This would prevent the awkward postures associated with carrying equipment out of the back of a smaller vehicle.

8.0 CONCLUSION

The costs of MSIs, medical costs and loss of duty time, are a burden to military populations. Austere working environments may increase the risk of occupational MSIs. AECMs are likely at risk of experiencing MSIs due to the physically demanding environments in which they work and the excessive lifting and reaching involved in AE tasks. This study characterized the ergonomic risks in the AE environment through a sampling study and observational techniques. These data identified the tasks that pose the greatest ergonomic risk to AECMs. This effort led to recommendations of materiel and process solutions to lower the risk of MSIs for AECMs. Future work may focus on task analysis for future AE platforms and a reassessment of risk following the implementation of solutions aimed at lowering the risk of MSIs in the AE environment.

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LIST OF ABBREVIATIONS AND ACRONYMS

AECM	aeromedical evacuation crewmember
BMI	body mass index
MSI	musculoskeletal injury
PTLOX	portable therapeutic liquid oxygen
QEC	Quick Exposure Check
USAFSAM	United States Air Force School of Aerospace Medicine